CLAIMS:

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1. A system for high dynamic range imaging comprising:

an image sensor comprising an array of light-sensing elements, the image sensor sensing an image of a scene and providing corresponding pixel values representing light intensities impinging on respective ones of the light-sensing elements, the image sensor providing a saturated pixel value when the intensity of light impinging on a corresponding one of the light-sensing elements is greater than a first threshold level and providing a blackened pixel value when the intensity of light impinging on a corresponding one of the light-sensing elements is below a second threshold level, the image sensor having a low dynamic range relative to the range of light intensities of the image of the scene;

a mask interposed between the scene and the array of light-sensing elements of the image sensor, the mask having a multiplicity of light-transmitting cells each controlling the exposure of a respective one or more of the light-sensing elements to light from the scene, each of the light-sensing elements having a corresponding exposure value indicative of the transparency of the cell through which light impinging on the light-sensing element passes;

a first memory storing exposure values corresponding to the light-sensing elements; and

an image processor coupled to the image sensor for receiving the pixel values provided thereby and coupled to the first memory for receiving the exposure values corresponding to the pixel values, the image processor comprising a normalizer for mapping the pixel values by a function of the exposure values to derive corresponding normalized pixel values.

2. The system according to claim 1, wherein the normalizer divides each of the pixel values with the exposure value corresponding to the light-sensing element receiving light intensity represented by the pixel value to derive corresponding normalized pixel values.

3. The system according to claim 1, wherein the exposure values corresponding to the light-sensing elements are fixed and the image processor further comprises an interpolator for interpolating the normalized pixel values to derive interpolated pixel values at respective positions of a second array overlapping the array of the light-sensing elements.

4. The system according to claim 3, wherein the interpolator of the image processor interpolates the normalized pixel values, excluding normalized pixel values corresponding to saturated pixel values or blackened pixel values.

5. The system according to claim 3, wherein the interpolator of the image processor interpolates the normalized pixel values multiplied by respective weighting values.

6. The system according to claim 5, wherein the weighting values are respective signal-to-noise ratios of the corresponding pixel values.

7. The system according to claim 3, wherein the interpolator of the image processor applies an interpolation filter to the normalized pixel values.

8. The system according to claim 3, wherein the light-sensing elements of the array are disposed at respective intersections of a first grid defined by spaced intersecting perpendicular lines extending in a vertical direction and a horizontal direction, and the interpolator derives interpolated pixel values at respective intersections of a second grid defined by spaced intersecting perpendicular lines extending in the vertical direction and in the horizontal direction, the first and second grids overlapping one another.

9. The system according to claim 8, wherein the interpolator of the image processor separately interpolates normalized pixel values in each different region of the first grid, each region overlapping adjacent regions and encompassing a predetermined number of intersections of the first grid.

10. The system according to claim 9, wherein the mask comprises repetitively disposed identical groups of cells having different transparencies.

11. The system according to claim 10, wherein each of the repetitively disposed identical groups of cells of the mask consists of four neighboring cells having different transparencies, each cell controlling the light exposure of a different one of the light-sensing elements, and the first and second grids have identical dimensions and are displaced from one another by one-half grid position in the horizontal direction and one-half grid position in the vertical direction.

12. The system according to claim 9, wherein the interpolator of the image processor derives a respective interpolated pixel value in each different region of the first grid by taking the average of all normalized pixel values in the region which do not correspond to a saturated pixel value or a blackened pixel value.

13. The system according to claim 1 further comprising a second memory storing a response function of the image sensor, wherein the image processor is coupled to the second memory for receiving the response function and further comprises a calibrator for converting the pixel values provided by the image sensor to linear response pixel values in accordance with the response function before the pixel values are normalized by the normalizer.

14. The system according to claim 3 further comprising an output image memory coupled to the image processor for receiving and storing the interpolated pixel values.

15. The system according to claim 1 further comprising a first lens system located between the scene and the mask for projecting an image of the scene onto the mask and a second lens system for projecting the image of the scene as transmitted through the mask onto the array of light-sensing elements.

16. The system according to claim 15, further comprising a light diffuser adjacent to the mask for removing directionality of light focused by the first lens system.

17. The system according to claim 1, wherein the array of light sensing elements is a solid state device image sensing device.

18. The system according to claim 17, wherein the solid state device is a charge-coupled device light sensing array.

19. The system according to claim 18, wherein the solid state device is a CMOS light-sensing array.

20. The system according to claim 17, wherein the mask is integrated with the light-sensing elements on the same substrate.

21. The system according to claim 1, wherein the mask is made of a nonlinear optical material.

22. A system for high dynamic range imaging comprising:

an image sensor comprising an array of light-sensing elements, the image sensor sensing an image of a scene and providing corresponding pixel values representing light intensities impinging on

respective ones of the light-sensing elements, the image sensor providing a saturated pixel value when the intensity of light impinging on a corresponding one of the light-sensing elements is greater than a first threshold level and providing a blackened pixel value when the intensity of light impinging on a corresponding one of the light-sensing elements is below a second threshold level, the image sensor having a low dynamic range relative to the range of intensities of the image of the scene;

a mask interposed between the scene and the array of light-sensing elements of the image sensor, the mask having a multiplicity of light-transmitting cells each controlling the exposure of a respective one or more of the light-sensing elements to the light from the scene, each of the light-sensing elements having a corresponding exposure value indicative of the transparency of the cells through which light impinging on the light-sensing element passes, the exposure value of each of the cells of the mask being alterable by applying a respective exposure control signal to the mask;

a mask controller coupled to the image sensor for receiving the pixel values provided thereby and for computing, and applying to the mask, exposure control signals for minimizing the number of saturated pixel values and blackened pixel values from the image sensor, and providing exposure values corresponding to the applied exposure control signals; and

an image processor coupled to the image sensor for receiving the pixel values provided thereby, the image sensor comprising a normalizer for mapping the pixel values by a function of the exposure values to derive corresponding normalized pixel values.

23. The system according to claim 22, wherein the normalizer of the image processor divides each of the pixel values by the exposure value corresponding to the light-sensing element receiving light intensity represented by the pixel value to derive corresponding normalized pixel values.

24. The system according to claim 22, further comprising an exposure pattern memory coupled to the mask controller for receiving and storing the exposure values, and wherein the image processor is coupled to the exposure pattern memory for receiving the exposure values corresponding to the pixel values from the image sensor.

25. The system according to claim 22 further comprising an output image memory coupled to the normalizer of the image processor for receiving and storing the normalized pixel values.

26. The system according to claim 24 further comprising:

a smoother coupled to the exposure pattern memory for receiving exposure values stored therein and applying a smoothing filter to the exposure values to derive smoothed exposure values corresponding to the normalized pixel values;

an exposure reapplicator coupled to the normalizer of the image processor for receiving the normalized pixel values and for multiplying each of the normalized pixel values with a corresponding smoothed exposure value to derive monitor image pixel values; and

a monitor image generator coupled to the exposure reapplicator for providing the monitor image pixel values.

27. The system according to claim 22, wherein the mask controller computes the exposure control signals to maximize the signal-to-noise ratio of the average pixel value provided by the image sensor.

28. The system according to claim 22, wherein the mask controller computes the exposure control signals to maximize the spatial smoothness of the exposure values corresponding to the light-sensing elements of the image sensor.

29. The system according to claim 22, wherein the mask comprises a liquid crystal array.

30. The system according to claim 22 further comprising a first lens system located between the scene and the mask for projecting an image of the scene onto the mask and a second lens system for projecting the image of the scene as transmitted through the mask onto the array of light-sensing elements.

31. The system according to claim 30 further comprising a light diffuser adjacent the mask for removing directionality of light focused onto the mask.

32. The system according to claim 22, wherein the array of light-sensing elements is a solid state image sensing device.

33. The system according to claim 32, wherein the solid state image sensing device is a charge coupled device light-sensing array.

34. The system according to claim 32, wherein the solid state image sensing device is a CMOS light-sensing array.

35. A system for high dynamic range imaging comprising:

an image sensor comprising an array of light-sensing elements, the image sensor sensing an image of a scene and providing corresponding pixel values representing light intensities impinging on respective ones of the light-sensing elements, each light-sensing element having a respective first threshold level so as to cause the image sensor to provide a saturated pixel value when the intensity of light impinging on the light-sensing element is greater than the respective first threshold level, each light-sensing element having a respective second threshold value so as to cause the image sensor to provide a blackened pixel value when the intensity of light impinging on the light-sensing element is below the respective second threshold level, the image sensor having a low dynamic range relative to the range of light intensities of the image of the scene, the light-sensing elements having respective spatially varying photosensitivies to incident light and corresponding photosensitivity values indicative of the respective photosensitivities

a first memory storing photosensitivity values corresponding to each of the light-sensing element; and

an image processor coupled to the array of light-sensing elements for receiving the pixel values provided by the image sensor and coupled to the first memory for receiving the photosensitivity values corresponding to the light-sensing elements, the image processor comprising a normalizer for mapping the pixel values by a function of the photosensitivity values to derive corresponding normalized pixel values, and an interpolator for interpolating the normalized pixel values to derive interpolated pixel values at respective positions of a second array overlapping the array of light-sensing elements.

36. The system according to claim 35, wherein the normalizer of the image processor maps the pixel values by a function of the photosensitivity values by dividing each of the pixel values by the photosensitivity value corresponding to the light-sensing element receiving light intensity represented by the pixel value.

37. The system according to claim 35, wherein the light-sensing elements of the image sensor are disposed at respective intersections of a first grid defined by spaced intersecting perpendicular lines extending in a vertical direction and a horizontal direction, and the positions of the interpolated pixel values are respective intersections of a second grid defined by spaced intersecting lines extending in the vertical direction and in the horizontal direction.

38. The system according to claim 37, wherein the interpolator of the image processor separately interpolates normalized pixel values in each different region of the first grid, each region overlapping adjacent regions and encompassing a predetermined number of intersections of the first grid.

39. The system according to claim 37, wherein the array of light-sensing elements of the image sensor comprises repetitively disposed identical groups of light-sensing elements having different photosensitivities.

40. The system according to claim 39, wherein in each of the repetitively disposed identical groups of light-sensing elements consists of four neighboring light-sensing elements having different photosensitivities, and the first and second grids having identical dimensions and are displaced from one another by one-half grid position in the horizontal direction and one-half grid position in the vertical direction.

41. The system according to claim 38, wherein the interpolator of the image processor derives a respective interpolated pixel value in each different region of the first grid by taking the average of all normalized pixel values in the region which do not correspond to a saturated pixel value or a blackened pixel value.

42. The system according to claim 35, wherein the image sensor has a respective response function to light impinging on each of the light-sensing elements and the system further comprises a second memory storing the respective response functions of the image sensor, and wherein the image processor is coupled to the second memory for receiving the response functions and further comprises a calibrator for converting the pixel values provided by the image sensor to linear response pixel values in accordance with the respective response functions before the pixel values are normalized by the normalizer.

43. The system according to claim 35, further comprising an output image memory coupled to the image processor for receiving and storing the interpolated pixel values.

44. A method for high dynamic range imaging comprising the steps of:

exposing an image sensor comprising an array of light-sensing elements to an image of a scene using a spatially varying exposure, the image sensor sensing the spatially varying exposure image and providing corresponding pixel values representing light intensities impinging on respective ones of the light-sensing elements, the image sensor providing a saturated pixel value when the intensity of light impinging on a corresponding one of the light-sensing elements is greater than a first threshold level and providing a blackened pixel value when the intensity of the light impinging on a corresponding one of the light-sensing elements is below a second threshold level, the image sensor having a low dynamic range relative to the range of light intensities of the image of the scene; and

normalizing the pixel values provided by the image sensor with respect to the spatially varying exposure of the light-sensing elements to derive corresponding normalized pixel values.

45. The method according to claim 44, wherein the step of exposing the image sensor using a spatially varying exposure includes the step of using a mask having a multiplicity of light transmitting cells each controlling the exposure of a respective one or more of the light-sensing elements of the image sensor to light from the scene, each of the light-sensing element having a corresponding exposure value indicative of the transparency of the mask cell through which light impinging on the light-sensing element passes, and the step of normalizing the pixel values provided by the image sensor includes the step of mapping the pixel values by a function of the exposure values to derive corresponding normalized pixel values.

46. The method accordiing to claim 45, wherein the step of mapping the pixel values by a function of the exposure values comprises dividing each of the pixel values with the exposure value corresponding to the light-sensing element receiving light intensity represented by the pixel value.

47. The method according to claim 44, wherein the exposure values corresponding to the light-sensing elements are fixed, and further comprising the step of interpolating the normalized pixel values to derive interpolated pixel values at respective positions of a second array overlapping the array of the light-sensing elements.

48. The method according to claim 44, wherein the step of interpolating the normalized pixel values include the step of applying an interpolation filter to the normalized pixel values.

49. The method according to claim 47, wherein the step of interpolating the normalized pixel values includes the steps of separately interpolating normalized pixel values in each different region of the array of the light-sensing elements, each region overlapping adjacent regions and encompassing a predetermined number of the light-sensing element positions.

50. The method of claim 49, wherein the steps of separately interpolating normalized pixel values in each different region of the array of light-sensing elements each include the step of taking the average of all normalized pixel values in the region, except for ones that correspond to a saturated pixel value or a blackened pixel value, to derive a respective one of the interpolated pixel values.

51. The method of claim 44 further comprising the step of calibrating the pixel values provided by the image sensor according to a response function of the image sensor to derive linear response pixel values before the step of normalizing the pixel values.

52. The method according to claim 47 further comprising the step of storing the interpolated pixel values in an output image memory.

53. The method of claim 45 further comprising the steps of projecting an image of the scene onto the mask, and projecting the image of the scene as transmitted through the mask onto the array of light-sensing elements.

54. The method of claim 53, wherein the step of projecting the image of the scene as transmitted through the mask onto the array of light-sensing elements includes projecting the image of the scene as transmitted through the mask and a light diffuser onto the array of light-sensing elements.

55. The method of claim 45, wherein the exposure value corresponding to each light-sensing element is alterable by applying a respective exposure control signal to the mask, and further comprising the steps of:

computing from the pixel values provided by the image sensor exposure control signals for minimizing the number of saturated pixel values and blackened pixel values from the image sensor;

applying the computed exposure control signals to the mask; and

providing exposure values corresponding to the applied exposure control signals for use in the normalizing step.

56. The method according to claim 55 further comprising the step of storing the normalized pixel values in an output image memory.

57. The method according to claim 55 further comprising the steps of:

smoothing the exposure values corresponding to the applied exposure control signals by applying a smoothing filter to the exposure values to derive smoothed exposure values corresponding to the normalized pixel values;

reapplying the smoothed exposure values to the normalized pixel values by multiplying each normalized pixel value with a corresponding smoothed exposure value to derive monitor image pixel values; and

storing the monitor image pixel values in a monitor image memory.

58. The method of claim 55, wherein the step of computing exposure control signals comprises computing exposure control signals to maximize the signal-to-noise ratio of the average pixel value provided by the image sensor.

59. The method according to claim 55, wherein the step of computing exposure control signals comprises computing exposure control signal to maximize the spatial smoothness of the corresponding exposure values.

60. A method for high dynamic range imaging comprising the steps of:

exposing a frame of photographic film to an image of a scene through a mask having a multiplicity of light transmitting cells controlling the exposures of respective regions of the film to light

from the scene, each of the respective regions of the film having a corresponding exposure value indicative of the transparency of the masked cell through which light impinging on the region passes;

storing the exposure values corresponding to the respective regions of the film;

processing the film to develop a masked image contained thereon or on a print thereof;

scanning the processed film or a print thereof with an image scanner to derive pixel values corresponding to the respective regions of the film or a print thereof; and

normalizing the pixel values from the scanner using the stored exposure values to derive normalized pixel values.

61. The method according to claim 60 further comprising the step of interpolating the normalized pixel values to derive interpolated pixel values.

62. The method according to claim 61 further comprising the step of storing the interpolated pixel values in an output image memory.

63. The method of claim 60 further comprising the step of aligning the pixel values corresponding to the respective regions of the film or a print thereof with the exposure values corresponding to the respective regions.

64. The method according to claim 60 further comprising the step of calibrating the pixel values corresponding to the respective regions of the film or a print thereof in accordance with a response function of the film, the image scanner and a printer, if any, to derive linearized pixel values before the step of normalizing the pixel values.